Measurement of Drell-Yan longitudinal double spin asymmetry in polarized *pp* collisions at PHENIX

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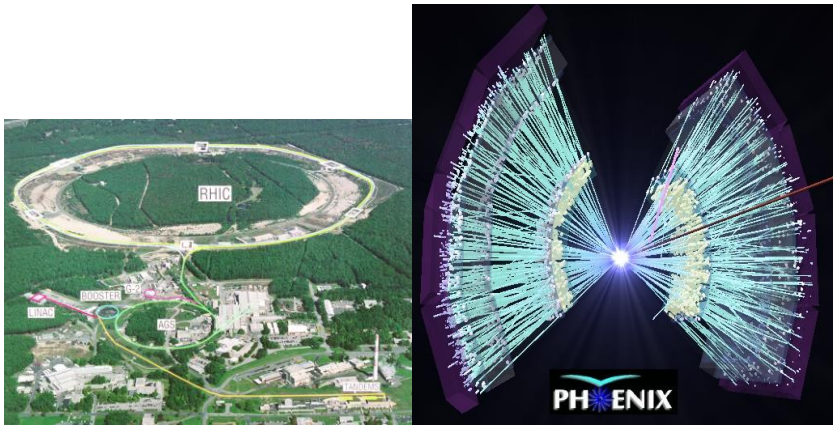


DNP October Meeting
14th October 2016 Vancouver, CA

UNIVERSITY of VIRGINIA

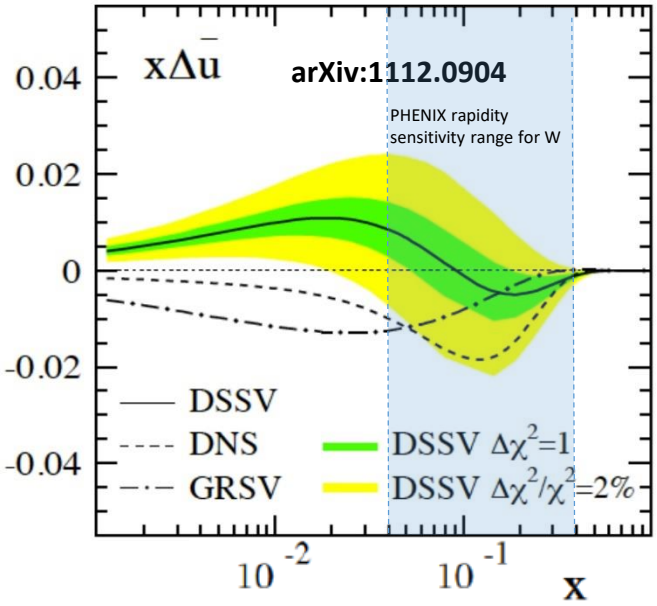
NM STATE UNIVERSITY

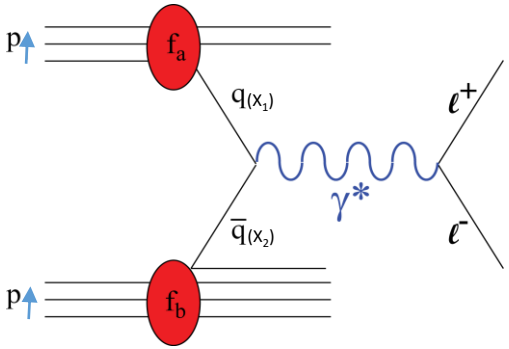
U.S. DEPARTMENT OF ENERGY

Motivation

- Spin dependent quark distribution
  Polarized Parton distribution function (pPDF)
  - $\Delta q(x)$: Δu and Δd are well known from the (SI)DIS data
  - $\Delta \bar{q}(x)$: $\Delta \bar{u}$ and $\Delta \bar{d}$ measured with larger uncertainties

- Drell-Yan A_{LL} can cleanly access $\Delta \bar{u} / \bar{u}$ which gives the anti-quark helicity distributions in the nucleon sea

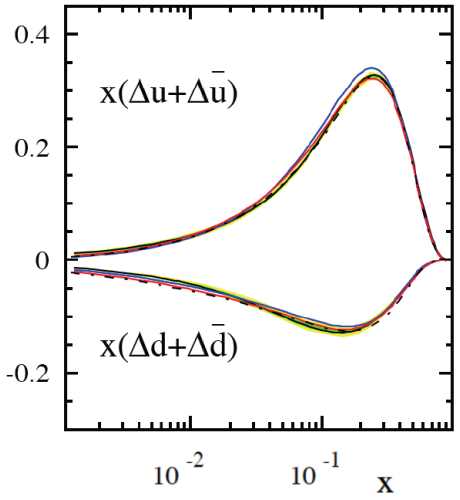




$$A_{LL}^{DY} = -\frac{\sum_q e_q^2\{\Delta q(x_1)\Delta\bar{q}(x_2) + \Delta\bar{q}(x_1)\Delta q(x_2)\}}{\sum_q e_q^2\{q(x_1)\bar{q}(x_2) + \bar{q}(x_1)q(x_2)\}}$$

$$\approx -\frac{\Delta u(x_1)}{u(x_1)} \cdot \frac{\Delta\bar{u}(x_2)}{\bar{u}(x_2)}$$

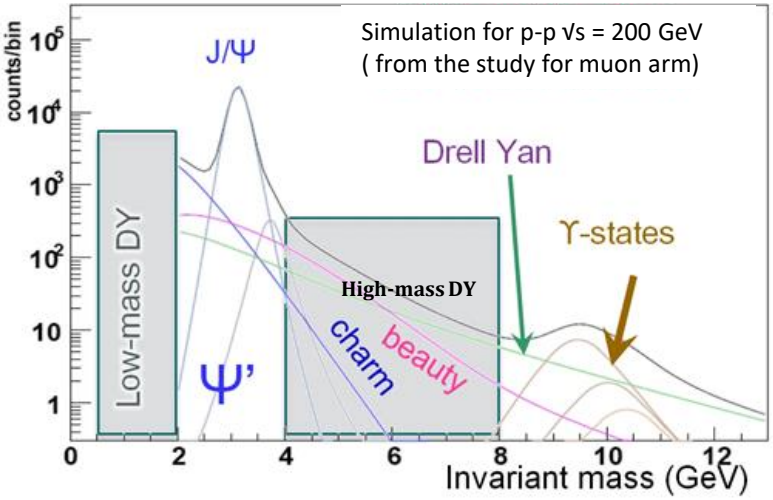
u-quark dominates in p+p
(84% of time Drell-Yan involves a u quark)

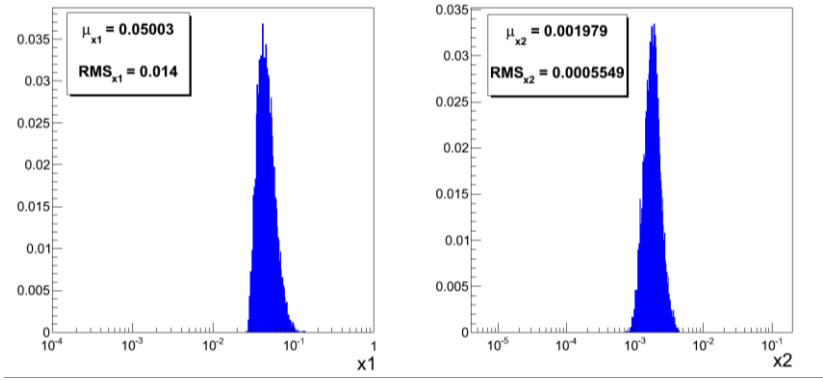


- No fragmentation functions are needed for the interpretation of Drell-Yan process

Drell-Yan Measurement at PHENIX

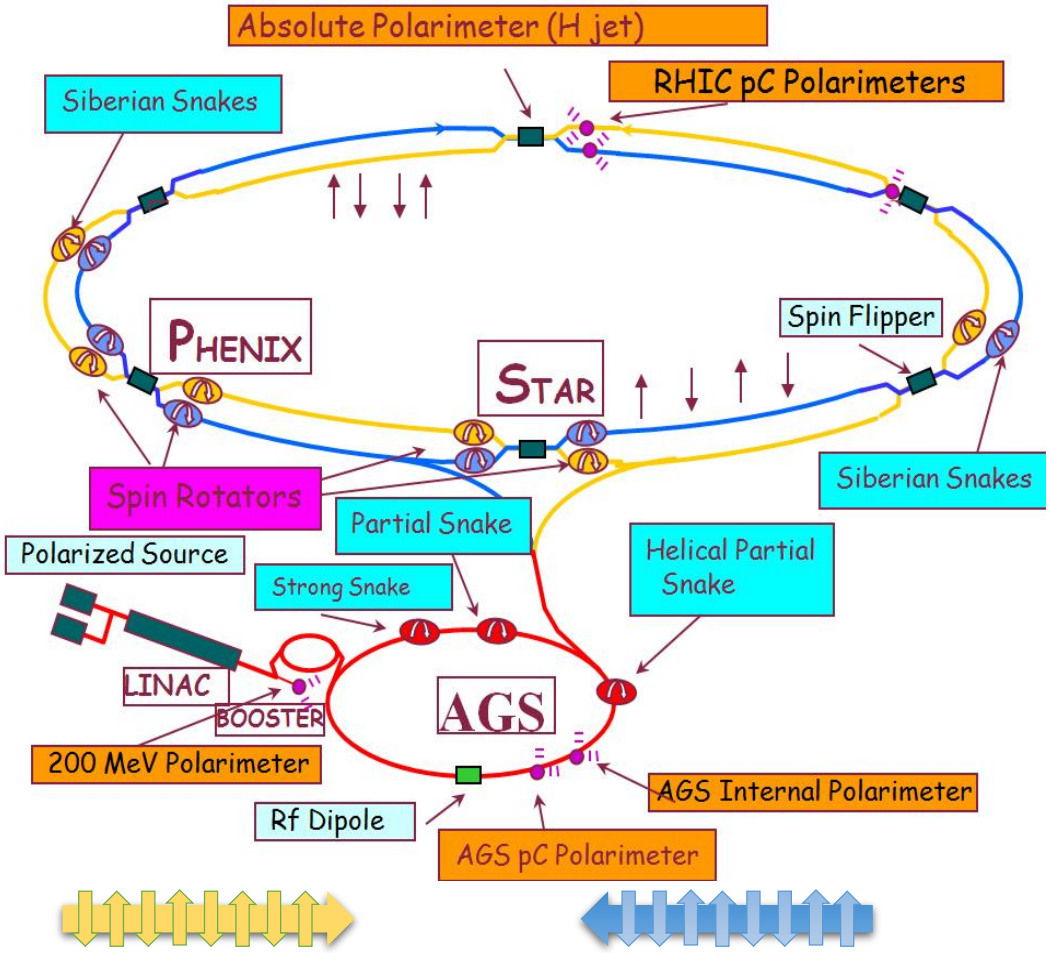
- We are interested in the Drell-Yan process between 4.5 GeV < M < 8 GeV of invariant mass
- We observe prompt muons from DY and Displaced muon tracks from heavy quark decays
- The PHENIX FVTX can help to reduce the dominant background from beauty decays in forward arm acceptance (1.2<|η|<2.4) in low x (~2×10^{-3}).
- The physics goal is to study the DY cross section, pT dependence, and relative yield of HF to DY
- These measurement will be used to extract double spin asymmetry (with limited statistics) and building towards the future measurements

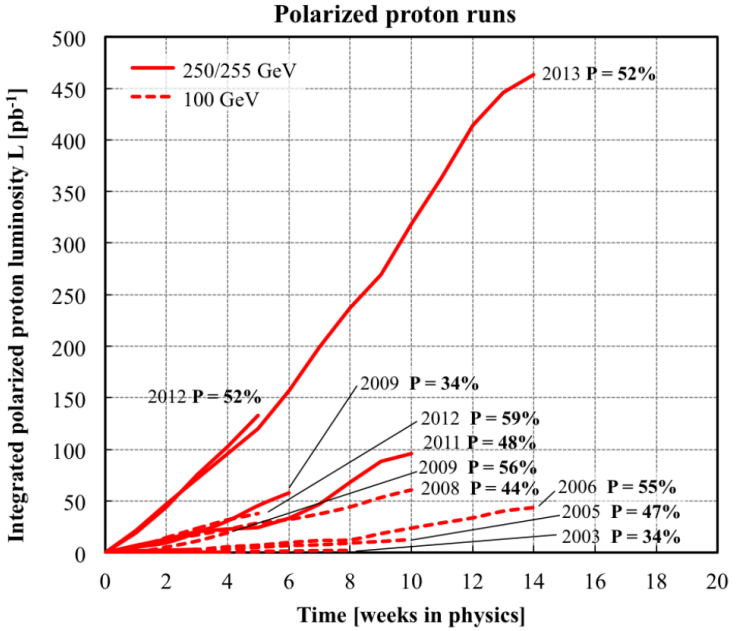




x_1 and x_2 in PHENIX Forward region for 510 GeV p + p

RHIC as a Polarized p + p Collider



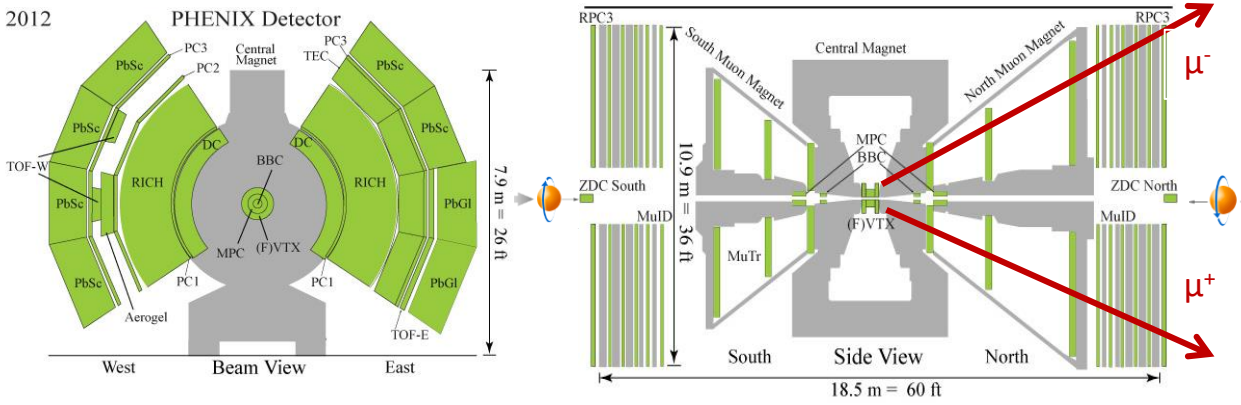


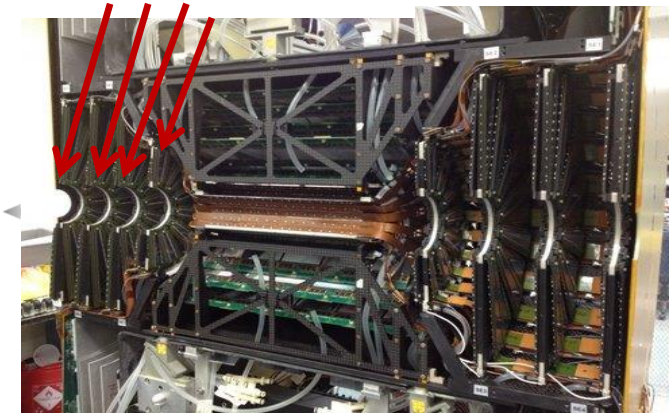
Run 12 Luminosity
- narrow vertex (|z|< 10 cm) : 10 pb^{-1}

Run 13 Luminosity
- narrow vertex (|z|< 10 cm) : 50 pb^{-1}

Run 12 Average Proton Polarization - 52%
Run 13 Average Proton Polarization - 52%

PHENIX Detectors





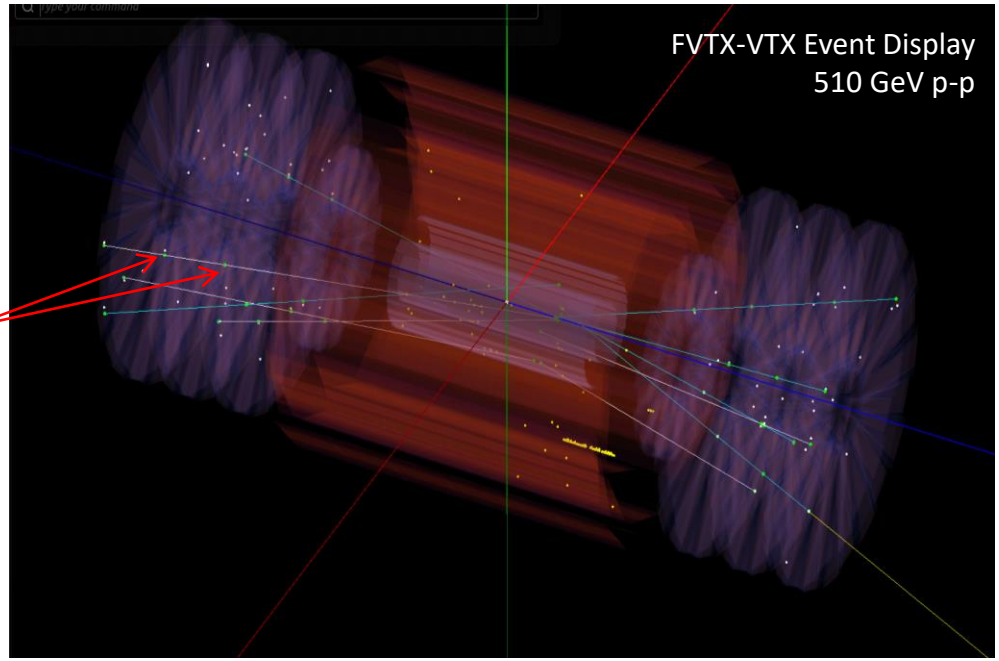
- Muons and Hadrons in the forward regions
  - Mu ID
  - Mu Trackers
  - RPC
  - FVTX

▪ FVTX for forward tracking

- ➢ 4 planes per end-cap
- ➢ Coverage
  - $1.2 < |\eta| < 2.4$
  - 2π in ϕ
  - $|z| < 15$ cm
- ➢ Resolution
  - Hit ~ 25μm
  - DCAR ~ 150μm (Combined VTX and FVTX)

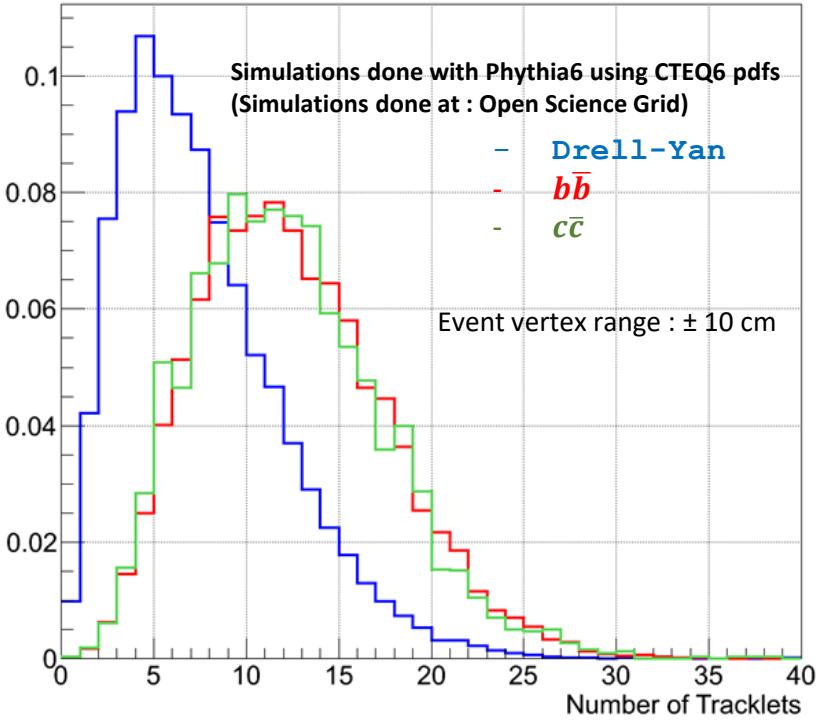
Introduction to Tracklets

2 or more hits reconstructs a tracklet

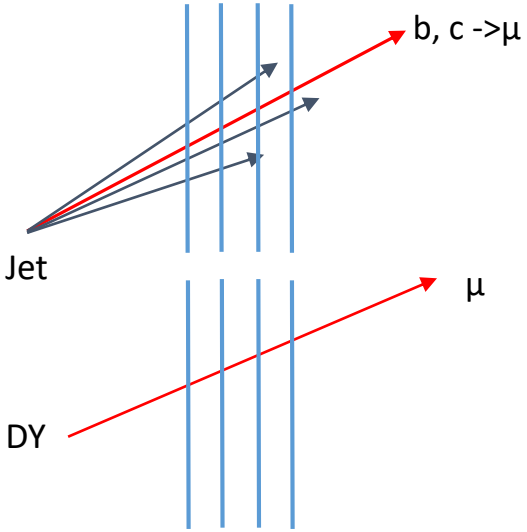


- Two hits in FVTX detector + the primary vertex / three hits in FVTX can be used to reconstruct a tracklet
- For each event, we observe tracklets in both arms of FVTX
- We count the number of tracklets pointing to the primary vertex

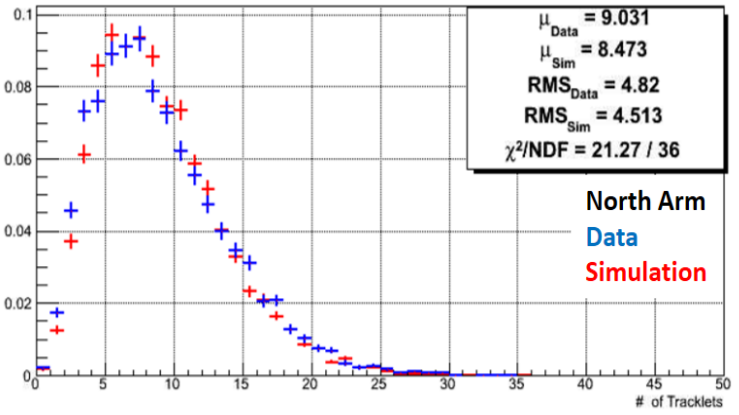
Comparison of the Tracklet Activity in FVTX



A jet generate more tracklets in FVTX than the Drell-Yan event

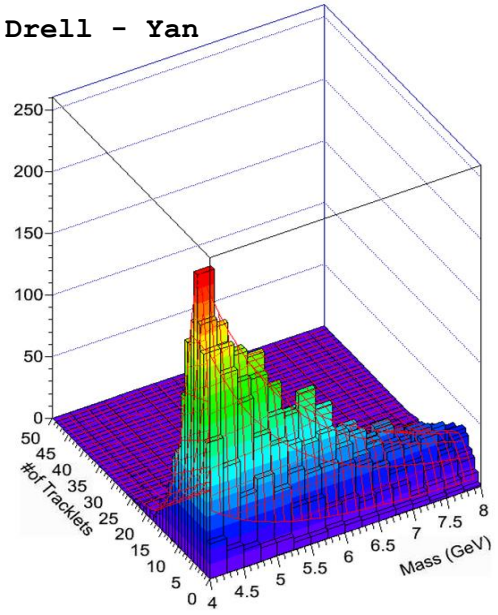


- The simulation show that the tracklet distribution in FVTX is a powerful tool to separate Drell-Yan from the heavy flavor backgrounds
- Comparison of J/Psi simulations and Run 13 Data shows that tracklet simulations match with the Data



Analysis Procedure

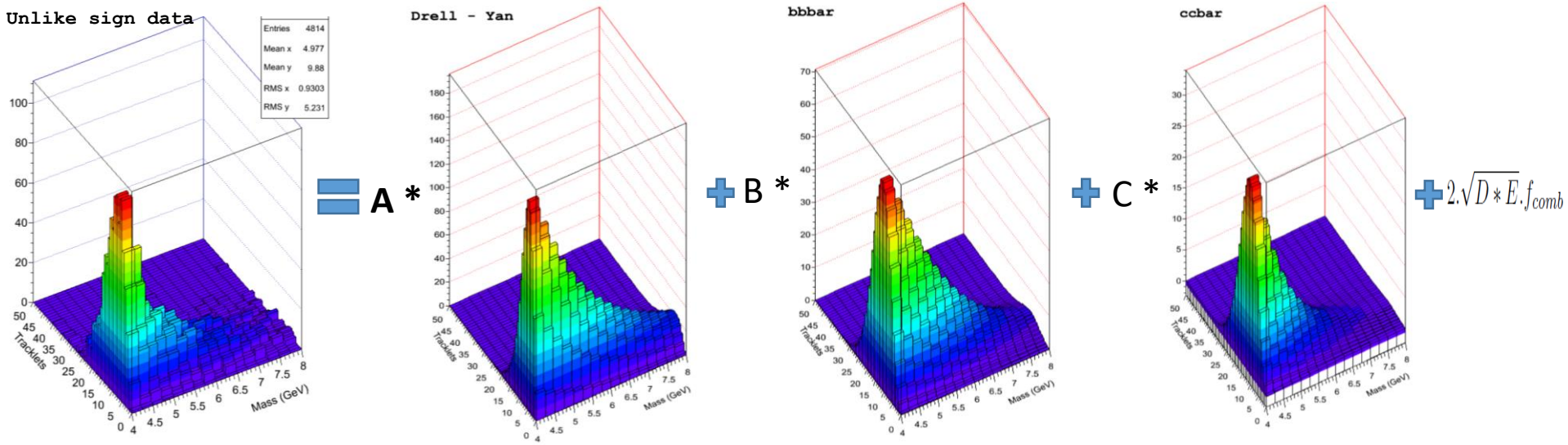
- Main challenge is to determine the signal fraction in our data
- Simulated events are plotted in to two dimensional histograms of Number of Tracklets Vs. Mass (For Drell-Yan, $b\bar{b}$ and $c\bar{c}$)
- Fit the histograms with 2-D functions and obtain the templates for the simulated signal and backgrounds



$$f_{DY}(x,y) = exp(ax + bx^2).\left(\frac{c + d * x}{e + f * x}\right)^{y/(e+f*x)}.$$

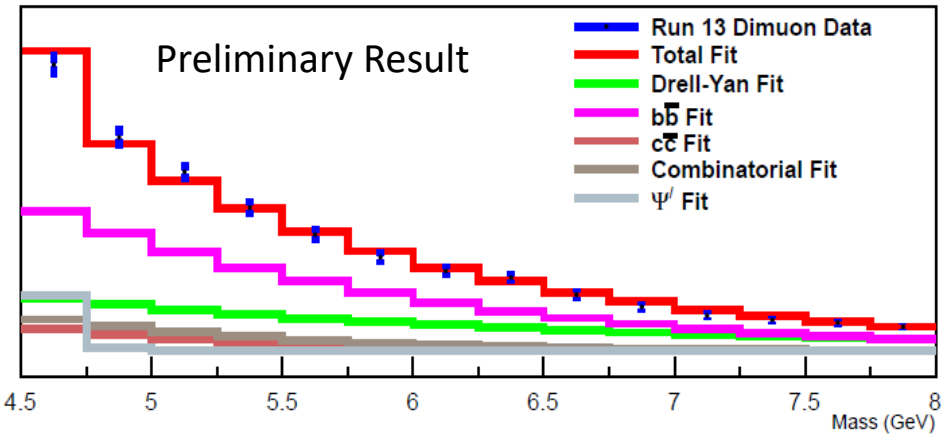
$$\frac{exp(-((c+dx)/(e+fx)))}{Gamma((y/(e+f*x))+1)}.(g + h * y + iy^2)$$

Analysis Procedure



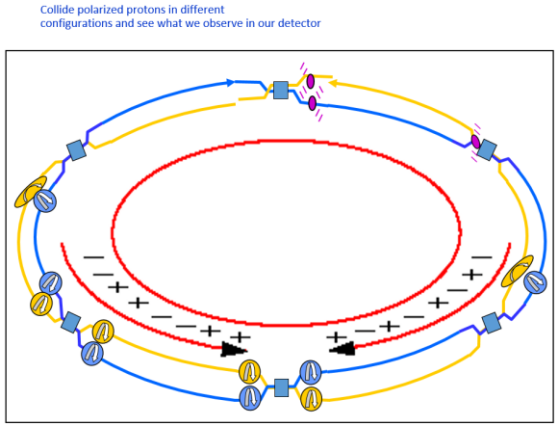
$$f^{+-}_{Final}(x,y) = A.f_{DY} + B.f_{b\bar{b}} + C.f_{c\bar{c}} + 2.\sqrt{D*E}.f_{comb}$$

D and E come from the likesign fitting



Analysis Procedure

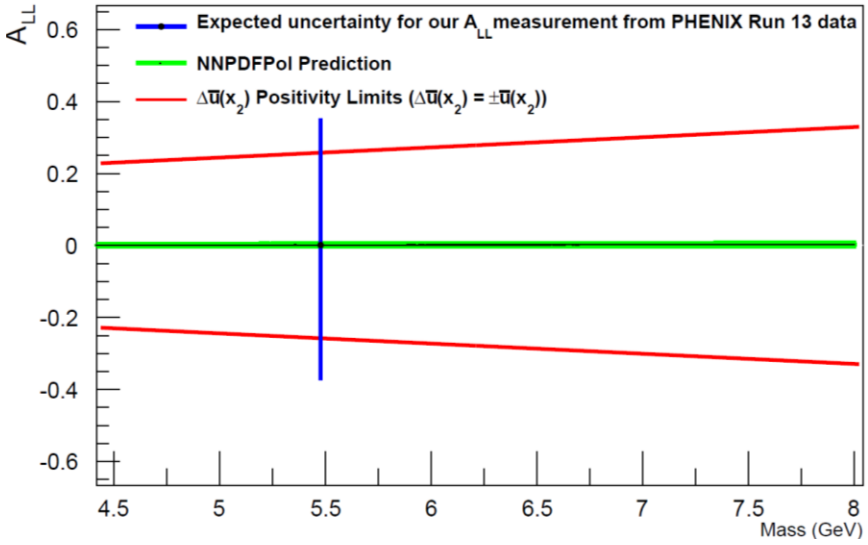
$$A_{LL} = \frac{\Delta\sigma}{\sigma} = \frac{1}{|P_1 P_2|} \frac{N_{++}/L_{++} - N_{+-}/L_{+-}}{N_{++}/L_{++} + N_{+-}/L_{+-}}$$



- Inclusive asymmetries and signal and background fractions are measured at two mass bins and four tracklet bins.
- Then they are used to extract the A_{LL}^{DY}.

$$A_{LL}^{inc} = (1 - F_{hf} - F_{comb}).A_{LL}^{DY} + F_{hf}.A_{LL}^{hf} + F_{comb}.A_{LL}^{comb}$$

F_x = Fraction for process x
$A_{ll}^{x} = A_{LL}$ for process x



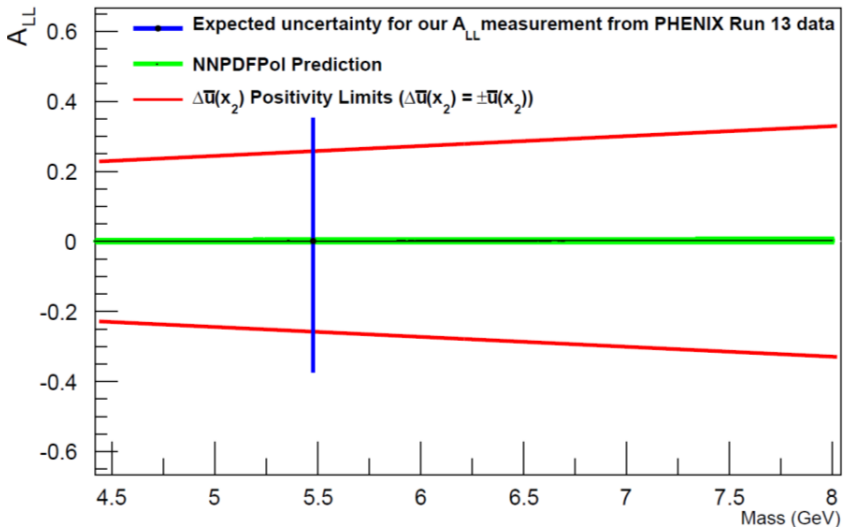
Summary

- Correlated $b\bar{b}$, $c\bar{c}$ and the combinatorial background are the sources of background for the Drell-Yan measurement for the high mass region

- PHENIX muon tracker and FVTX play a major role in the forward arm Drell-Yan Measurements

- Analysis Method for determining signal fraction: Likelihood fitting with 2-D templates
  - Tracklet count distribution Vs Mass

- Measured quantities
  - Measuring the Drell-Yan signal fraction
  - Measuring the Drell-Yan longitudinal double spin asymmetry
- Currently, we are working on
  - Measure the Drell-Yan cross section



Backup

Backup

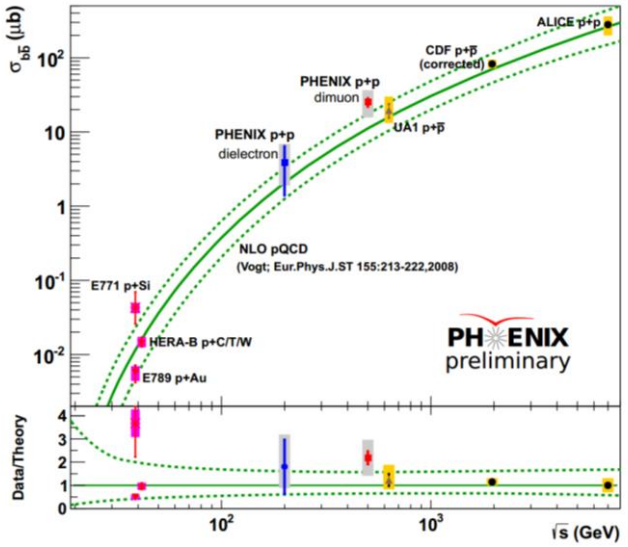


Figure 6.17: Comparison of $\sigma_{b\bar{b}}$ at different center of mass energies with NLO pQCD theory. The data point labeled "dimuon" is from this analysis. The bottom panel shows the ratio of data to NLO theory.